Using Advanced Prosthetics for Stress Inoculation Training and to Teach Life Saving Skills

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ABSTRACT

This paper discusses new developments in advanced medical technology which may in the short term be applicable to NATO multinational medical operations. To supply more realistic military medical training, The Virtual Reality Medical Center (VRMC) conceptualized and developed a unique injury simulator as an adjunct to current combat medic training. This initial technology, called Injury Creation Science (ICS), very realistically simulated a number of battlefield injuries such as amputations, eviscerations, blast injuries, punctures, and burns. Since the initial prototypes, VRMC has developed this technology into wearable "part-task trainers" that simulate injuries as well as allow combat medics to practice actual medical procedures common to the battlefield. The progression of these "trainers" has been under the guidance and partnership with the U.S. Army Research and Engineering Command – Simulation and Technology Training Center (RDECOM – STTC). The procedures currently available or under development include treatment of pneumothorax, hemoperitonium, and gunshot wounds to an artery. By integrating medical science with cutting edge simulation and training technologies, realistic prosthetic tissue, wounds, and part task trainers have been developed for the training of trauma care clinicians. The next generation of Stress Inoculation Training (SIT) includes the use of prosthetics developed based on human anatomy and physiology, material science, and nanotechnology. Testing has revealed that these products are highly useful and reliable and can easily be integrated into existing protocols for enhancement of the training experience.

1.0 NEXT GENERATION INJURY CREATION SCIENCE

A Government Accountability Office (GAO) report released in 1998 stated that military medical personnel have little to no practice with battlefield trauma care skills during peacetime. An additional report by the National Library of Medicine's Institute of Medicine indicated that approximately 98,000 individuals in the U.S. die each year as a result of medical practice mistakes. Most current medical simulation training relies on plastic forms, computerized mannequins, animals, and cadavers. Each of these has significant drawbacks, such as incorrect anatomy (animals), lack of realism (plastic forms and mannequins), limited use (cadavers), and expense. In addition, they do not replicate the majority of injuries encountered on the battlefield [1].

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The Injury Creation Science (ICS) technology was developed to embody an injury simulation capability that includes the curriculum and prosthetics required to train medical professionals in procedures to include bypassing a compromised airway, inserting an intravenous port, preventing blood loss as a result of arterial and venous wounds, dressing burns, and expanding a collapsed lung.

Front line medics face major challenges created by severe medical trauma. The military currently invests millions of dollars to train its soldiers, however, there remains much room for improvement in current training methods for combat medics. Many existing scenarios employ some type of simulation, however, due to limited realism their ability to fully immerse the trainee into combat medical situations has been called into question. Fully experiencing the scenario is exactly the kind of experience that will properly prepare medics to deal appropriately with actual battlefield injuries including broken bones, lacerations, amputations, severe bleeding and tissue damage. In addition, many civilian-trained medical personnel and first responders do not receive sufficient psychological preparation to aptly handle severe wartime traumatic injuries. ICS's Stress Inoculation Training works to address the need to provide skills based training under increasingly stressful conditions offering high levels of realism to provide optimized performance under fire and other stressful conditions.

The Virtual Reality Medical Center (VRMC) conceptualized and developed a unique injury simulator to supply more realistic military medical training. ICS acts as an adjunct to current combat medic training and does not seek to replace it. Initial ICS technology was found to very realistically simulate a number of battlefield injuries such as amputations, eviscerations, blast injuries, punctures, and burns. Since the initial prototypes were developed, VRMC has expanded this technology into wearable "part-task trainers" that simulate injuries as well as allow combat medics to realistically practice tangible medical procedures common to the battlefield. The progression of these "trainers" has been under the guidance and partnership with the U.S. Army Research and Engineering Command – Simulation and Technology Training Center (RDECOM – STTC). The procedures currently developed include treatment of pneumothorax, hemoperitonium, and gunshot wounds to an artery.

According to a paper given at the first symposium on Modeling and Simulation for Computer-Aided Medicine and Surgery [2] the ultimate medical simulation is a highly realistic setting in which the participant actually perspires, the heart rate goes up, and he or she reacts in a manner that is consistent with a real environment, a reaction which can be obtained through virtual reality (VR) or other realistic forms of simulation.

For over fifteen years, The Virtual Reality Medical Center (VRMC) has been developing training and assessment protocols based on both subjective and objective measures in our clinic, particularly by pioneering the use of physiological measures while trainees perform exercises in VR and other simulation environments. Our expertise provides the military with immersive training that produces the psychological hardening necessary to prepare troops for front line experience.

In order to create more realistic military medical training, funding was awarded from the Telemedicine and Advanced Technologies Research Center (TATRC) to conceptualize and develop a unique injury simulator for use in Echelons I and II: the Injury Creation Science (ICS) prototype. Additional funding from RDECOM allowed us to produce hyperrealistic training kits for advanced trauma procedures. VRMC consulted with Department of Defense personnel to create this novel technology using movie-making techniques and special effects to complement current combat casualty care simulations. We identified combat injuries and medical and surgical procedures for inclusion in the prototype and experimented with makeup techniques to design realistic injuries, including "dynamic" injuries.

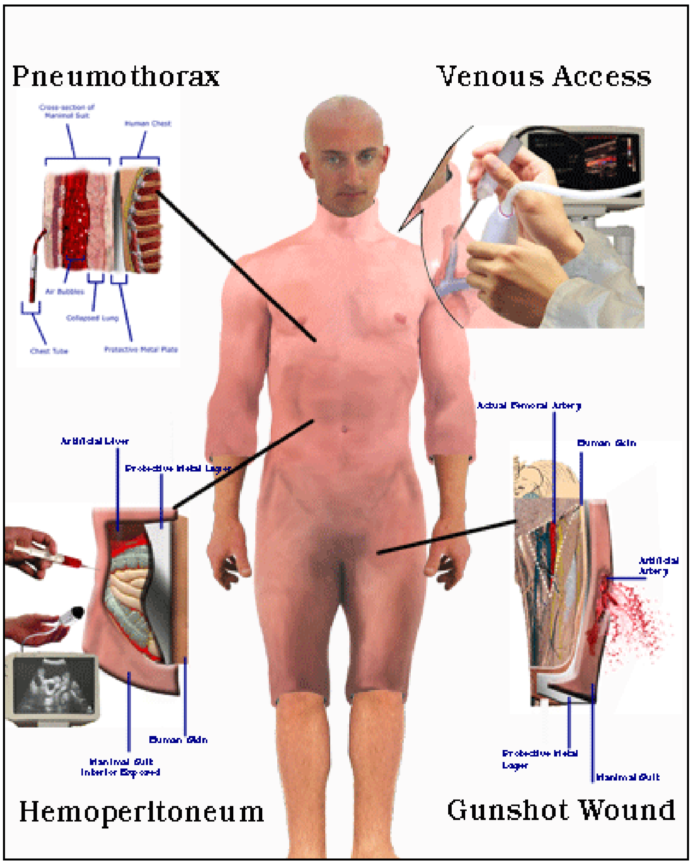

Figure 1: Developed by VRMC, the Injury Creation Science prototype is a training device that is worn like a second skin and has the ability to recreate realistic injuries, including "dynamic" injuries, by employing Hollywood makeup techniques and special effects.

The approach we have taken in the creation of a new type of artificial skin relies on our careful study and evaluation of the microanatomic structure of the components of the layers of the skin. In addition, we have carefully noted each component of each layer of the skin and how each of these components contribute to the microelastic viscous and other important physiological attributes of living tissue are integrated together. To further assist us, we have sought out both materials and expertise involving selection of potential substances from nanotechnology substrates. The search for appropriate nanotechnology materials is ongoing and an important component of our research and development efforts.

These medical appliances can be used with mannequins or live human actors. While mannequins are generally well accepted by trainees, they do not bleed convincingly during simulation, and different mannequins must often be used to represent patients with different injuries, body types, and age groups [3]. By basing the trainer on a visually realistic simulation and using a material sciences approach to anatomy, ICS seeks to conquer previous deficits in realism. Advantages obtained by having a real person wear the simulator is that they can both look and act like a real patient. For example, they can be told to writhe, cry out in pain, distract the medic, and give wrong medical information. Mantovani et al. (2003) underscore the value of VR to potentially enhance a complex set of skills that includes the often-neglected personal aspects of patient care. Having a "patient" wear the simulator, as we describe, goes beyond mere VR to create actual person-to-person interaction in simulated medical emergency situations [4].

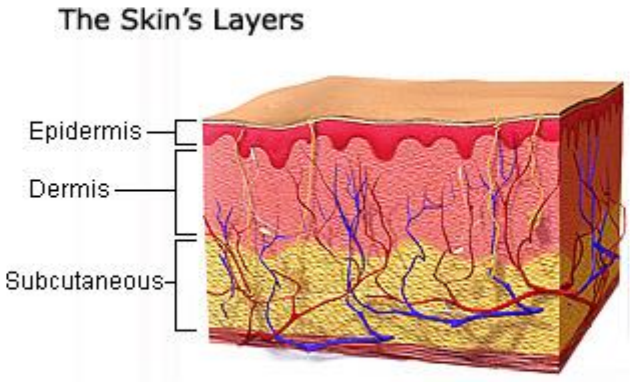

Figure 2: We will begin by studying the microanatomy of skin in preparation of synthetically reproducing its multiple layers.

The year 1834 marked the beginning of wound simulation, or "moulage," with artists painting injuries on the body for military mass casualty exercises. Moulage filled a role more for the benefit of the military maneuvers organizers than for the trainee, since the level of realism at the individual medic or corpsman level was reported as low. Hollywood makeup and theatre techniques allowed new elements of realism to be added, such as blood and open fractures. These, in general, however, have not been used extensively in military simulation training. Various companies offer casualty simulation kits online for trauma training. These are generally comprised of "stick-on" wounds with a limited subgroup of "bleeding moulage," and are medically realistic, but only visually so. Forensic science simulations focus more closely on scientific realism than Hollywood moulage techniques and currently employ simulated tissue and bone to test the effect of ballistics. Synthetic body parts are also used for performance testing of helmet and body armor.

Synthetic simulants of the forensic variety can be divided into three categories: soft tissue, skin, and bone simulants. The literature focus most closely on soft tissue simulants, with elasticity and non-collapsibility being important qualities. Numerous substances, including wood, clay, soap and paraffin, have been used to study bullet effects in simulated tissue [5]. Special manufactured glycerin soap and hydrogels prepared from water solutions have been used successfully to simulate muscle tissue [6, 7]. The use of the transparent candle gel for ballistic testing was first noted in a 2003 study by Uzar et al. Through suspension of animal organs and bones in blocks of the gel Ozer [8] created organ and lower extremity injuries. Ballistic experimenters favor the translucent quality of gelatin and gels to clearly show bullet paths and fragments for measuring purposes but this is less important for surgical simulation [9].

Although simulated skin has been studied much less than simulated tissue, animal skin has been used for some injury simulation studies. Jussila notes the use of simulated skin increases the fidelity of experiments involving low-velocity projectile injuries or effects such as ricochets. Thali, Kneubuehl, Zollinger & Dirnhofer [10] created an artificial head they call the "skin-skull-brain model" using a silicon cap with synthetic fibers on a polyurethane skull to simulate skin. The silicon cap, composed of artificial leather, prevents the bone fragments from scattering after the model has been struck by gunfire. Bone simulant research can be found in the forensic science literature as well as in biomaterials research. Bone engineering in the biomaterials field, however, concentrates on grafts and resorbable biomaterials as temporary scaffolds and so does not easily lend itself to injury simulation [11, 12, 13].

Kneubuehl and Thali (2004) developed an artificial bone made from polyurethane to compare gunshot wounds to swine bones. The design, patterned after human bone structure, consisted of a compact outer layer covering a porous inner layer [14]. Ordnance gelatin injected into the bone's hollow core simulated marrow and a covering of latex simulated the periosteum. The comparison between the biological swine bones and the non-biological model in regard to loss of velocity and energy after striking bone, bone fragmentation, bullet deformation, and penetrating wound channel were entirely equal. Other studies shed

doubt on the similarity in terms of longitudinal fractures but still achieve good, consistent results [9]. A Swiss company, Synbone AG, manufactures artificial bones designed for teaching orthopedic techniques in fracture repair, and this type of product is being examined in the development of ICS.

Trauma care skills and experience are crucial in the successful resuscitation and operative care of injured patients. Both initial learning as well as maintenance of skills is problematic due to a lack of training opportunities. Studies have shown that VR trauma simulators are likely to provide the best long-term answer to this problem. As summed up by Satava and Jones (1999), “The benefits of virtual reality to healthcare can be summarized in a single word: revolutionary [15].”

An array of medical simulation technology has been funded by the Department of Defense in recent years. Most of this can be grouped into the following four categories:

1) PC-based decision teaching tools (e.g., STATCare)
2) Digitally enhanced mannequins (e.g., Combat Trauma Patient Simulator)
3) Virtual workbench technology (e.g., HT Medical Systems)
4) Total immersion VR (e.g., Center for Integration of Medicine and Innovative Technology).

Current state of the art medical simulators, however, have significant drawbacks, especially in terms of verisimilitude. A comparison of the ICS wearable synthetic skin model to commonly used surgical simulation methods is summarized in the table below.

Table 1: Comparison of Surgical Simulation Methods
Adapted from Kaufmann, C.R. (2001) [16].

Model	Strengths	Weaknesses
Animal	Bleeding, individually inexpensive	Ethics/animal rights, anatomy incorrect, single use, logistics
Cadaver	Anatomy correct	Expensive, storage issues, single use, no bleeding
Plastic model	Inexpensive, convenient, repeat use	Realism, needle tracks
Computerized mannequin	Multiple applications, repeat use	Realism, very expensive, precut holes
Virtual reality (VR)	Unlimited use, practice without instructor, multiple scenarios, control degree of difficulty, reset	Realism variable, expense variable, haptic force limitation
ICS Wearable Synthetic Tissue	***Inexpensive, multiple applications, repeat use, “bleeding,” safe and easy to put on, behaves like real patient***	***Future challenge: train in SIT scenarios → test on mannequin or human → refine SIT scenarios***

The ICS prosthetics were initially designed for use during training and preparation of military medics to accurately stabilize fallen warriors during combat. The initial goals were to: 1) enhance realism to ensure an immersive training experience, 2) minimize application/removal time, 3) increase prosthetic durability and reusability, and 4) increase comfort. The prosthetics, packaged as self-contained kits, include prosthetic wounds and all required supplies to apply and enhance injuries to provide an immersive training experience. Some criticisms of existing injury simulations are that application requires a specialized skill set and significant application time, and that the prosthetic is neither reusable nor durable in most cases. Additionally, existing prosthetic wounds are often unrealistic and uncomfortable to wear. The ICS prosthetic wound solves these problems; it is physiologically accurate, highly durable, very

comfortable to wear, and most importantly, ready-made, minimizing the skill and time required for application.

The ICS technology is focused on research and development in support of the combat casualty care training mission. This training includes Basic Life Support, Patient Assessment, Hemorrhage Control, Fracture Management, and Shock Prevention & Treatment. By merging the latest special effects technology with material science research, the ICS team is developing prosthetic human tissue and wounds for realistic live training. This technology is critical for the trauma care training kits being used by the U.S. Army to train combat medics. This same technology is being transitioned to assist with similar training requirements in the civil sector for Emergency Management, Disaster Management, and First Responder personnel. The technology has also been used to assist training of Special Forces personnel in PfP countries.

The first product developed, the ICS Simple Kit, provides for the application of prosthetic entry, exit, and shrapnel wounds for live training exercises and focuses on enhancing realism. The Simple Kit was validated during extensive factory testing, and a training exercise that was held at the University of Florida (UF) Center for Simulation Education and Safety Research (CSESaR), among others.

The initial research revealed important information that has been useful in further refining of the ICS prosthetics. In particular, quantification of physiochemical properties of skin and tissue have been found in both biochemical and structural clues. For example, skin water content and elastic properties are important contributors to the look, feel, and texture of skin. We have noted that the water content of skin increases from the surface to deeper levels. In addition, connective tissue components have been identified which provide a basis upon which to begin modification of existing artificial substances aimed at improving the level of realism in artificial tissue. Several non-invasive and minimally invasive technologies have been identified which will assist in the creation of new synthetic materials that reproduce the critical aspects of tissue. Based on these findings, we continue to refine the technologies, and search for polymers that have a graded hydration component.

VRMC and RDECOM-STTC recently partnered to significantly increase the medical realism of prosthetic injury simulation appliances. The collaboration offered the opportunities for further laboratory research and to develop improved materials that simulate the smell and feel of human tissue and fluids. The VRMC/RDECOM-STTC Integrated Product Team (IPT) refined the simulated skin and tissue of the earlier prototypes and built upon it to better replicate wounds for medical training. The skin was engineered based upon the configuration of the actual layers present in skin. Candidate silicone formulas were matched to the skin's layers through spectral analysis and nanotechnology applications. Furthermore, the immersion experience was enhanced through the incorporation of olfactory components into the synthetic materials.

Studying human tissue using spectroscopy was critical to further developing the ICS technology. We used spectral analysis to evaluate the early ICS prototypes, and explored ways to improve them based on the quantitative data acquired during testing. With this data, we compared ICS prototypes to the properties of human skin. Additional work remains in this area and possible outcomes include identifying existing materials for simulation effects, developing hybrids, and developing completely new materials and methodologies.

Initial research indicated that although transparent silicone appliances would be favorable in terms of flexibility and packaging in the kits, these would require make-up expertise skills or training. The IPT decided that the prosthetic appliances would be colored inherently to require minimal application steps and that in order to maximize ease of use, three shades of skin tone were developed to be used in the prototype kits.

The prosthetic appliances were designed to affix to a human actor or mannequin as a patch, and consist of simulated skin, underlying tissue, representations of organs or structures, and a protective layer next to the wearer's skin.

2.0 STRESS INOCULATION TRAINING (SIT)

Stress Inoculation Training (SIT) is often the umbrella term used to represent a collection of coping strategies provided to the trainee. Developed in the late 1970s by Donald Meichenbaum, SIT was originally designed for use with multiple populations of individuals [17]. Often thought of as "mental armor", SIT helps to "inoculate" individuals to future potentially traumatizing stressors, teaching them to psychologically deal more effectively with the stressors [18, 19]. In 1988, a National Research Council study on enhancing military performance found that when a person is given knowledge of future events, stress surrounding those events is then reduced [20]. In general, this occurs because stress is associated with a new, novel task. Stress training therefore renders the task less novel and improves the trainee's self-efficacy, which in turn improves performance.

During preventative SIT, military personnel "experience" highly stressful situations in a virtual environment while being physiologically monitored. Repeated exposure enables personnel to gradually become desensitized to stimuli that may initially elicit such strong physiologic arousal that performance is impeded (i.e., "freezing in the line of fire") and psychological trauma is more likely. In SIT, individuals are provided with a tool kit of coping strategies, thus allowing them to construct a personalized coping package and choose those strategies most efficacious for their individual needs and for the particular situation. These skill sets are developed with the goal of helping with immediate needs as well as future stressful situations in a proactive defense against trauma. Some of the traditional components used in a SIT regimen include didactic teaching, problem solving, cognitive restructuring, imaginal rehearsal, behavioral rehearsal, relaxation training, self-instruction, self-monitoring, and self-reinforcement. The three distinct stages of SIT include conceptualization, skills acquisition and rehearsal, and application and follow-through.

Figure 3: VRMC is experienced at creating highly realistic scenarios to train combat medics. Here, trainees work on a simulated "dynamic" wound, which bleeds and reacts to treatment.

SIT builds on our clinical work with exposure therapy for anxiety disorders, including PTSD [21, 22, 23, 24, 25, 26], and our work in developing and testing SIT protocols to prepare troops for deployment to war zones. In addition to the training provided to U.S. forces, we have to-date provided training to coalition troops including those in Croatia, Romania, Poland, and Hungary. Providing over 7,000 treatment sessions for a variety of psychological disorders through a combination of cognitive-behavioral therapy and physiological monitoring, we note that successful treatment of stress and anxiety-related disorders is

achieved through skills-based exposure training to increasingly stressful situations, allowing the patient to over-learn coping skills and develop a sense of mastery, with the ultimate goal of improved performance and self-confidence in one's ability.

In our ongoing SIT studies, we train military personnel in virtual environments such as an Iraqi village, a shoot house, or a ship. Simulations can be viewed on desktops, laptops, through a head-mounted display (HMD), or as a 3-wall CAVE (computer automatic virtual environment) projection system, depending on the needs of the specific population to be trained. The training is then transferred to real-world exercises in structures designed specifically for tactical training.

3.0 COMBINING SIT AND MEDICAL TRAINING FOR COMBAT MEDICS

VRMC's Student State Assessment, a 3-year study funded by Defense Advanced Research Projects Agency (DARPA) completed in July 2005, included a combat medic training scenario in which medics received SIT training using the ICS simulator prototype. In these scenarios, we simulated bleeding resulting from "dynamic" injuries. In addition, trainees were able to cut the "skin," insert a chest tube, and stitch the wound closed. (A lightweight metal plate underlying the suit protected the "patient.") The feedback received from trainees was that it was the most intense, realistic training they had ever received.

During the combat medic training, VRMC was able to experiment with simulations that went beyond moulage, or static makeup techniques. For example, we created a wound complete with active bleeding that stopped when a tourniquet was applied. In other cases, where compression was more difficult and bleeding continued, we were able to fill large IV bags with special-effects blood and deliver tubing to the injury site so as to create brisk bleeding from the wound. In another case, we created a chest wound and hid a tube that delivered air to the chest injury site. The "wounded" soldier could squeeze a bulb hidden in his hand to simulate air bubbles at the chest wound site with each breath. While we were able to try other types of injuries, it became clear to us that the tubing and other pieces that add to the special effects really need to be properly engineered, as in some cases the devices became detached. Although many basic issues need to be explored, this effort has significant potential to greatly augment training.

The table below illustrates how we will leverage all of our experience with related funded projects for this new effort to develop improved synthetic tissue for training medics in front line care, both in terms of hands-on medical instruction and stress management **(Table 2).**

Significant transfer of skills from virtual training to real-world exercises has been demonstrated in experiments with the U.S. Army, Navy SEALs and Corpsmen, Marine Corps, Coast Guard, and Drug Enforcement Agency personnel. Repeated exposure to stressful stimuli combined with immediate physiological feedback, provides the tools for helping law enforcement personnel achieve peak performance. In addition to providing state-of-the-art training for military law enforcement and first responders, other uses include trauma care training for the civilian population and scenarios for mental health care delivery.

Table 2: VRMC Programs to Leverage for Synthetic Tissue Development.

VRMC Programs	***Purpose***	***How Leveraged***
TATRC Next Generation Injury Creation Simulator	Train combat medics and other medical professionals	injury creator prototype; testing protocols
TATRC Stress Inoculation Training (SIT) software for Aeromedical professionals	Train flight surgeons, flight medics, and flight psychologists at USAARL, Ft. Rucker, Alabama	SIT training specifically for military medical personnel
DARPA Virtual Shoot House Virtual Reality Videogame (VRVG)	MOUT training and testing for joint forces and for echelon one combat trauma care	SIT training specifically for military medical personnel
ONR virtual reality software for PTSD treatment with SIT option	Test VR therapy with 136 US Navy Seabees and medical personnel who have acute PTSD stemming from combat exposure	Combat medic training; data collected from training stress response both pre and post deployment
TATRC Combat Medic using Virtual Reality Videogames (91W)	Provide an inexpensive training tool that will allow medics to experience situations outside of their everyday training	Medical and SIT training and testing for combat medics

We have studied lessons learned from the tactical decision-making under stress (TADMUS) exercise, which resulted from the mistaken shooting down by the U.S. Navy of a commercial Iranian airliner. The study has some important information about training in virtual worlds and other types of simulated environments. Essentially, trainees must learn under stress and complexity conditions similar to what they will encounter in real life. This may seem obvious, but transitioning training from simulators to the real world is still an active issue under intense investigation. Below is a comparison chart that contrasts the lessons learned from the TADMUS study with lessons learned from our clinical experience, and from our contract with the Defense Advanced Research Projects Agency (DARPA).

Table 3: Application of VRMC SIT Training Paradigm Based on TADMUS and Applied to Medical Training.

	TADMUS	VRMC (Civilian)	VRMC (DARPA)	VRMC (RDECOM)
	Stress Exposure Training	**Cognitive Behavioral Therapy**	**Student State Individual Training**	**Combat Medic Training**
Education	Information provision	Patient education	Individual training	Skills Training
Skill Building	Skill acquisition and practice	Physiological feedback and training	Stress inoculation, skill acquisition and practice	Improved performance under stress
Cognitive Schema	Confidence building – application and practice	Cognitive coping techniques, desensitization in virtual reality, then *in vivo* (real life)	Cognitive thought processes – expected behaviors, sequence of procedures	Correctly follow medical algorithms
Degree of Exposure	Over-learn	Over-learn	Over-learn	Over-learn
Training Generalization	Training generalizes to real-life missions	Therapy generalizes to real-life situations	Training generalizes to real-life tasks and missions	Training generalizes to real-life tasks and missions
Content Generalization	Skills generalize to novel tasks and novel stressors	Other phobias not specifically trained show improvement	Skills generalize to multiple missions and tasks	Skills generalize despite unique anatomic attributes
Method of Exposure	Gradual increase in stressors results in skill building	Gradual exposure is important	Train in neutral environments, then in tactical situations	Train in increasingly difficult environments
VR Advantages	Virtual reality simulations crucial in allowing for a gradual increase in stressors	Virtual reality simulations allow for over-learning and gradual exposure to increasingly intense situations	Training on simulators is as effective as training in real-world settings	Virtual training for medical applications is underdeveloped
Internal Belief	A sense of control and mastery occurs	Self-efficacy and a sense of mastery occurs	Sense of confidence and mastery of skill sets occurs	Sense of confidence and mastery of skill sets occurs
Ongoing Support	Refresher sessions provide maintenance of skills	Booster sessions provide maintenance of skills	Strong user acceptance and portability prevent skill decrement	Refresher training and recertification are possible
Pace of Exposure	Initial exposure to high-demand/high-stress conditions does not result in skill development and generalization	Flooding does not result in development of skills	Temporal contiguity of simulation training to real-world training is important in skill building	Gradually increase the complexity of medical complications for mastery

	TADMUS	VRMC (Civilian)	VRMC (DARPA)	VRMC (RDECOM)
Order of Exposure	Develop basic physiological control strategies first to control stress/reduce attention allocated to emotions	Teach physiological control first	Complete the cognitive and associative phases of learning first	Pairing of cognitive and stress hardening skills is preferred
Quality of Exposure	Absolute fidelity is not necessary or desirable	Virtual reality simulations better than real video	Face validity and low fidelity are requirements for successful completion of the cognitive and associative phases of learning	Fidelity and continuous improvement in physical characteristics is important
Lessons Learned	**Take-home message**: "An effective method for reducing anxiety and enhancing performance in stressful environments. The results of this analysis should clearly encourage further application and research" (Cannon-Bowers and Salas, 1998).	**Take-home message**: CBT reduces anxiety, results in higher levels of functioning, and increases quality of life.	**Take-home message:** The laptop simulator is an effective method of training individuals to carry out mission-specific tasks.	**Take-home message:** Combining both medical skills and stress hardening is crucial not only for optimal performance but the prevention of PTSD

4.0 OBJECTIVE MEASUREMENTS OF TRAINING TRANSFER

An important part of the next generation injury creation science program is the ability to accurately quantitate the effectiveness of training. In general useful metrics allow for prediction of percentage of improved performance, reduction in the number of errors, and the overall efficiency of the training program. We were able to develop very accurate and exacting training transfer metrics in our DARPA Student State Program. This program focused on urban warfare training in Iraq. Specific objectives such as room clearing, weapons identification and room takedown were accurately and objectively measured in both the virtual training environment and the real performance environment. To a certain extent this program provided easy to identify endpoints and metrics of success. For example, the time it takes to clear a room ca be accurately measured through analysis of video feedback. Examples of this kind of objective measure are shown in the table below.

Table 4: VRMC/ DARPA Result.

Activity Performed	VR Trained Scores	Non-VR Trained Scores
Proper ID & Breach Technique	Utilized proper breaching tool 100% of the time. Identified outward door 27.8% more effectively.	Utilized the proper tool 80% of the time.
Room Clearing	5-man team took an average of 9 seconds to clear the room.	Took an average of 11 seconds.
Take Down Objective	Took 21 minutes to secure the objective with 100% accuracy.	Took 23 minutes with only 93.8% accuracy.
Sketching the House	Exhibited 80% accuracy and sketched house in 4 minutes.	Exhibited 50% accuracy and sketched house in 6 minutes.
Identify Contraband, Weapons, and Other Significant Materials	Correctly identified and collected 50% of these materials.	Only identified and collected 30% of these materials.
Fastrope	Total time of 1256 seconds. (17.2% faster)	Total time of 1517 seconds.
Caving Ladder	Total time of 1657 seconds. (8.3% faster)	Total time of 1807 seconds.

VRMC has sufficient evidence that this training transfer theory is valid. The improvement in performance following the virtual training suggests the anticipated benefit was indeed realized. In every category tested, the VR trained soldiers completed the missions faster and had better accuracy in doing so, thus proving that skills learned do transfer from VR to real-world training.

The DARPA project "Physiological Monitoring during Training and Testing" was successful in applying off-the-shelf video games to their training methods. The effectiveness of video games as a teaching tool can be found in many other off-the-shelf games as well, each game contributing differently toward cognitive development in the players.

In another DARPA funded study, we evaluated the physiological responses of trainees during a virtual combat medic video game task performance. In this experiment combat medics who were inserted into dismounted patrols encountered a variety of medical emergencies while under fire. These scenarios were sufficiently challenging that significant physiological arousal occurred during the performance of the virtual tasks. Our ongoing research will continue to evaluate performance and training transfer metrics while trainees undergo performance of trauma, triage, assessment, and treatment protocols. Our model for training medical personnel is in part based on the original TADMUS study which we used initially to construct a training paradigm for improving urban warfare skills. We believe this theoretical model will be useful in constructing and then validating the most effective model in the training of medical personnel. Another significant advantage of the NG-ICS program is that it may substitute for the treatment of real life injuries which are very difficult to schedule and arrange appropriate training for. There remains much work, however, when considering the most important and the most appropriate training outcomes for medical personnel.

5.0 CONCLUSIONS

The ICS prosthetics have proven to be useful and reliable and provide a realistic training experience for health care professionals. After evaluating data from the U.S. Army Institute for Surgical Research, it is

clear that a need exists for part task trainers to prepare military trauma care professionals for life saving procedures necessary to preserve the life of wounded war fighters. Many of these same procedures are done in civilian hospitals. Identifying common needs between field medicine and civilian hospitals can help reduce the estimated 98,000 people that die each year as a result of medical errors. It is imperative that we continue to train medical personnel by employing the highest level of fidelity and realism and leveraging the lessons learned from military training to civilian medicine.

Moving forward, VRMC and RDECOM-STTC are employing state of the art techniques and materials in the development of physiologically accurate synthetic tissue, a critical technology in the development of dynamic wound and medical procedure kits. In addition to the work cited in this paper, current research and development is focused on creating the next generation of kits, which include the materials required to train emergency medical personnel in performing a cricothyrotomy and chest tube insertion. The collaborative partnership between VRMC and RDECOM-STTC provides product validation. We are refining prosthetic tissue technology and transitioning this capability to medical training applications.

Implicit in developing this new technology is the ability to weave in the important lessons we are learning from Stress Inoculation Training. Most medical training does not include a stress-hardening component when based upon reports of high levels of stress and PTSD in medical personnel obviates the need for improved attention to this growing problem. It is our opinion that the SIT component may be equally as important to the acquisition of appropriate medical triage and trauma training skills.

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